RESEARCH CIRCULAR 245 JANUARY 1979

Integrated Control of Insects and Mites on Greenhouse Crops

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ACKNOWLEDGMENTS

The authors gratefully acknowledge the contributions of Glenn L. Berkey (photos) and Newell H. Hartrum (graphs) of the Department of Public Information.

AGDEX 256-257-286/614-625-626 1-79-2.5M

Integrated Control of Insects and Mites on Greenhouse Crops

RICHARD K. LINDQUIST, CAROL FROST, and MILDRED L. WOLGAMOTT[1]

INTRODUCTION

Crops grown under protected cultivation present unique problems and opportunities for insect and mite control. The lack of natural environmental checks creates an excellent situation for rapid increase of pest populations, but also makes the introduction of environmental controls (*e.g.*, natural enemies) potentially easier than on similar crops grown in the field.

Integrated pest management (IPM) programs for pests of vegetable and ornamental crops grown under protected cultivation are used in Europe and Canada. Most programs involve rearing and introducing an aphelinid parasite wasp, *Encarsia formosa* (Gahan) (Figs. 1A, 1B), to suppress the greenhouse whitefly, *Trialeurodes vaporariorum* (Westw) (Fig. 2), and/or a phytoseid predaceous mite, *Phytoseiulus persimilis* (Athias-Henriot) (Fig. 3), to control the two-spotted spider mite, *Tetranychus urticae* (Koch) (Fig. 4). Selective pesticides and/or application methods are used in conjunction with natural enemies.

Encarsia is a small wasp that lays its eggs in developing whitefly nymphs or "scales" (Fig. 5). The parasite larva then feeds on the young whitefly and kills it. Fig. 6 indicates how the host and parasite life cycles fit together.

Phytoseiulus mites are very mobile and feed on all stages of *T. urticae,* consuming several mites and eggs each day. *Phytoseiulus* reproduce faster than *T. urticae* at normal greenhouse temperatures and so are very effective predators, eventually eliminating their prey. Selected pesticides, application methods, and disease-resistant cultivars are also used to reduce incidence of other pests.

BRIEF HISTORY

The IPM approach to insect and mite control on greenhouse crops began in England during the late 1920's, when *Encarsia* was widely used to control the greenhouse whitefly on tomatoes. No precise methods were developed for introducing the parasites and results were variable. Following the development of synthetic organic pesticides in the 1940's and 1950's, use of *Encarsia* was discontinued (3, 7, 8).

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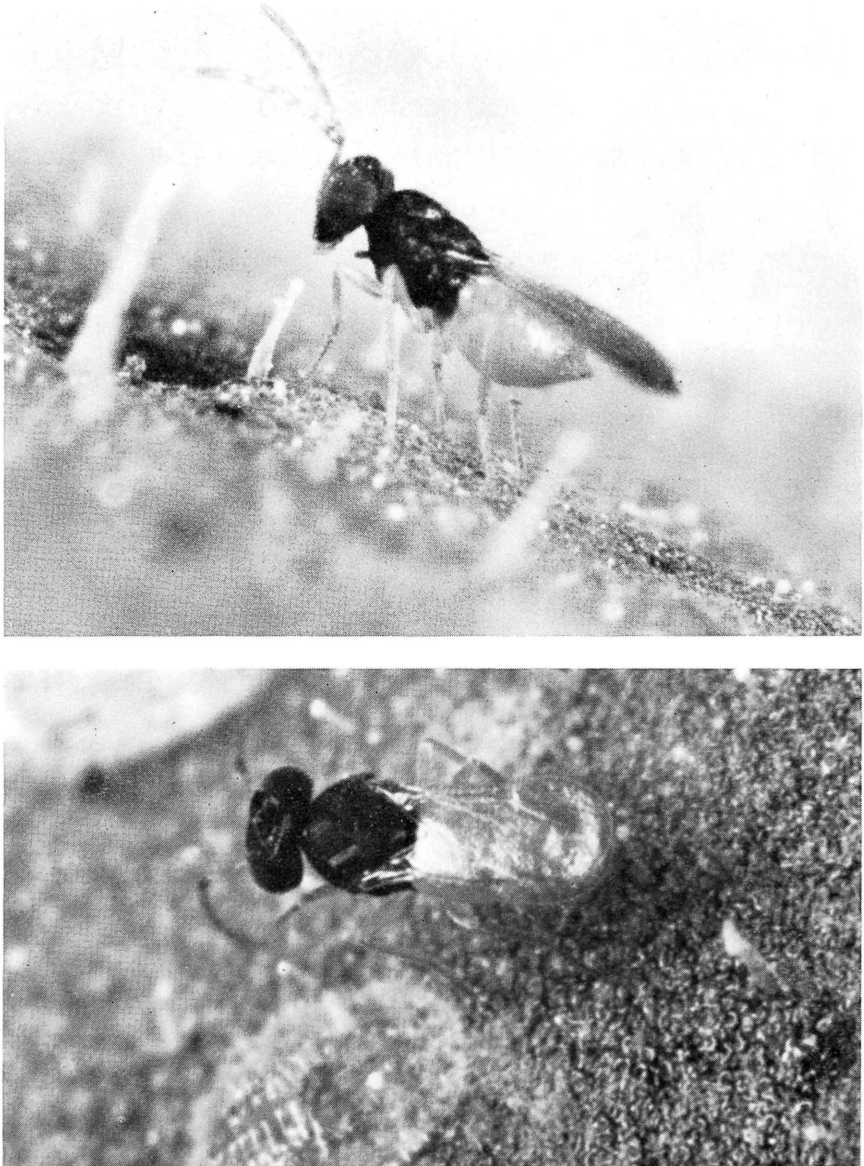


FIG. 1.—*Encarsia formosa* **(top);** *Encarsia formosa* **and whitefly nymphs (below).**

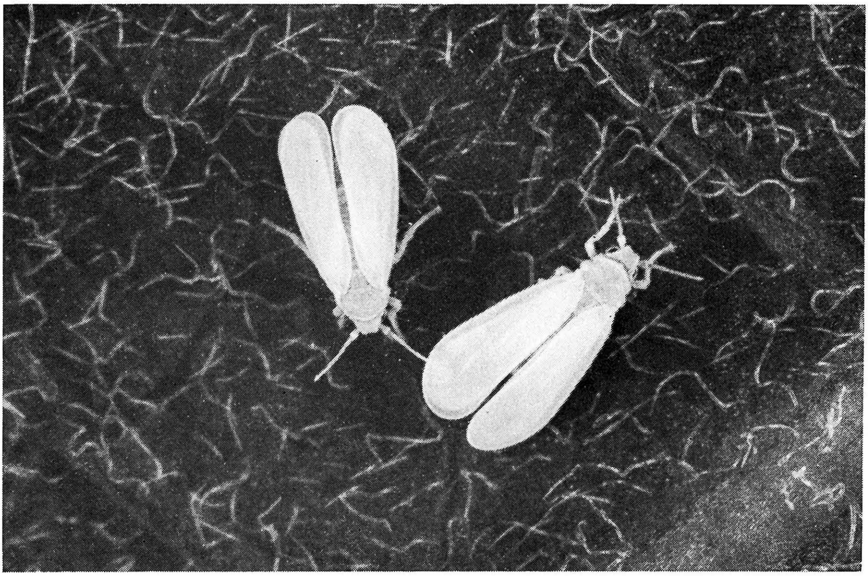


FIG. 2.—Adult whiteflies, Trialeurodes vaporariorum.

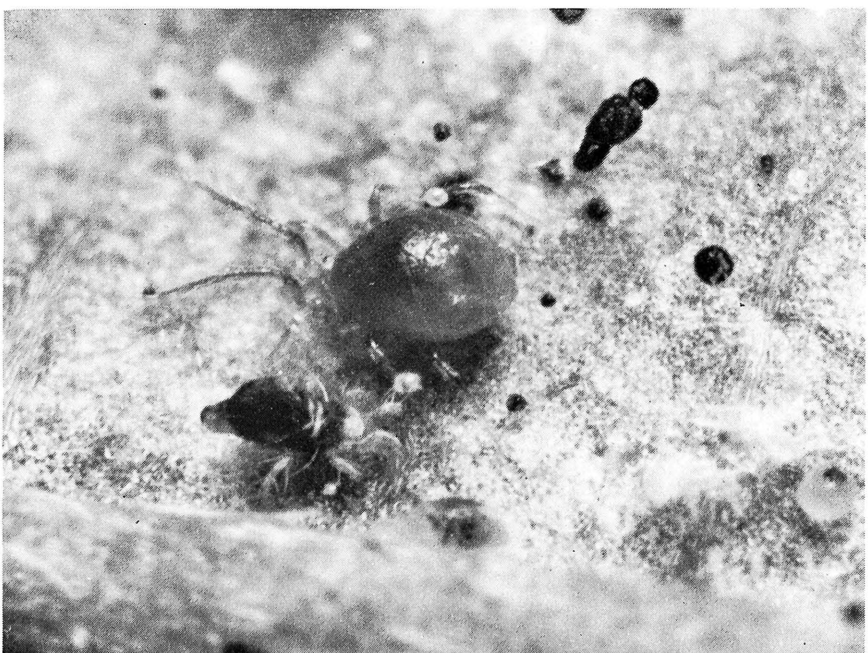


FIG. 3.—Phytoseiulus persimilis.

The next burst of interest in using natural enemies came in the 1960's when large populations of two-spotted spider mites became resistant to many pesticides and were severe pests of cucumbers. *Phytoseiulus* was used to control *T. urticae* and practical techniques were developed for introduction and monitoring of populations (2, 3). When *Phytoseiulus* mites were introduced, pesticide use had to be minimal; so *Encarsia* was again utilized for whitefly control on cucumbers and tomatoes and methods of introduction were developed (3, 8).

Much of the credit for developing the procedures currently used goes to researchers at the Glasshouse Crops Research Institute (GCRI) in Littlehampton, England (Hussey, Scopes, Parr, *et al*), and the Research Station for Vegetables and Fruit under Glass in Naaldwijk, The Netherlands (Bravenboer, Woets). Many others have been involved in adapting the basic procedures to growing systems in their respective countries.

Some form of IPM on commercial greenhouse vegetable crops is now used in nearly all European countries and Canada. Table 1 from Woets (12) summarizes this information for Europe. In The Netherlands, for example, these areas are from a total of 4,700 ha (11,750 a) devoted to vegetable production.

Although the major reason for development of IPM on greenhouse crops was pesticide resistance, other advantages (in addition to delaying

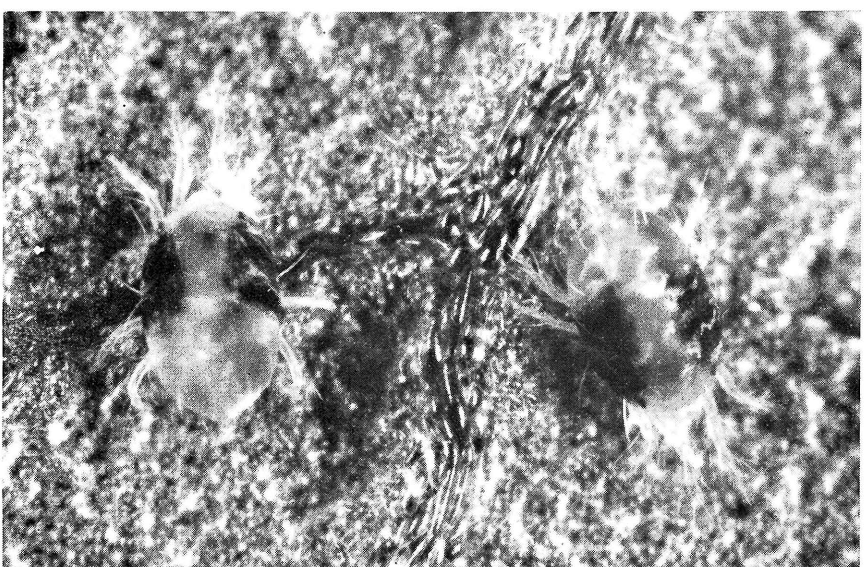


FIG. 4.—Two-spotted spider mites, Tetranychus urticae.

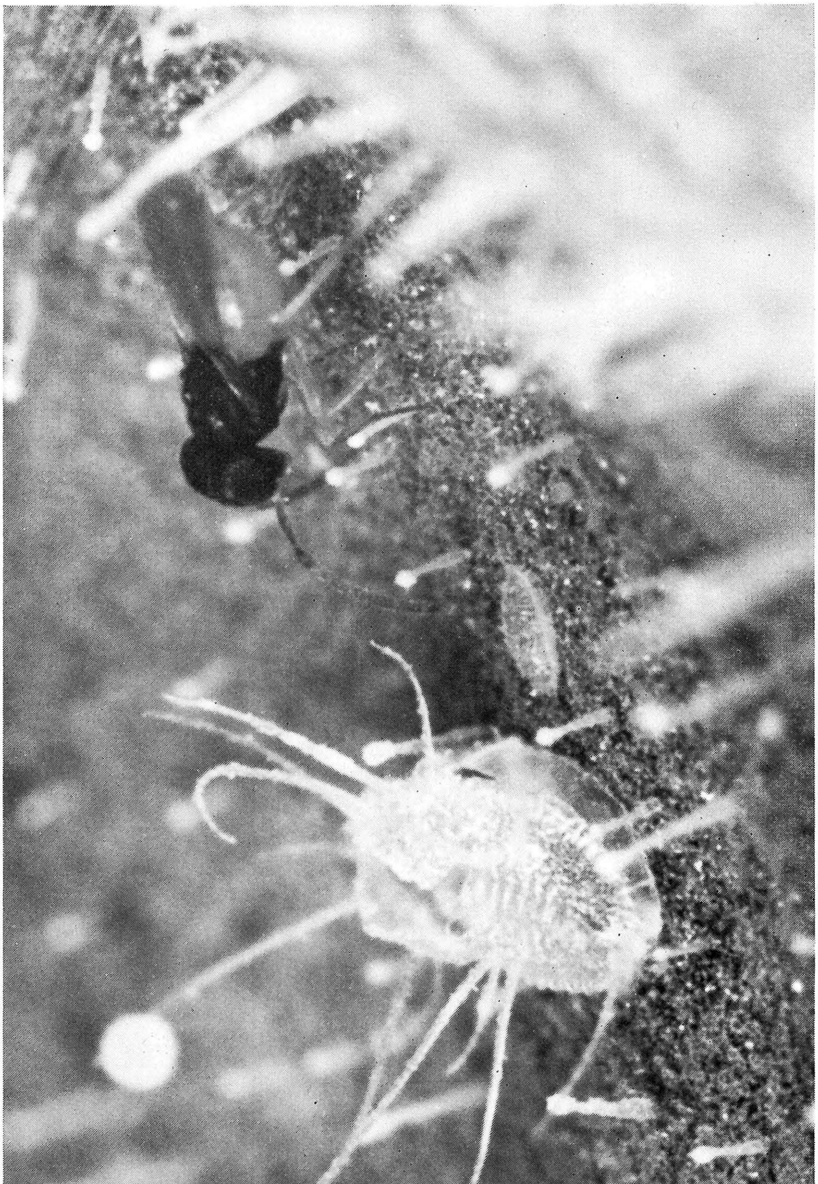
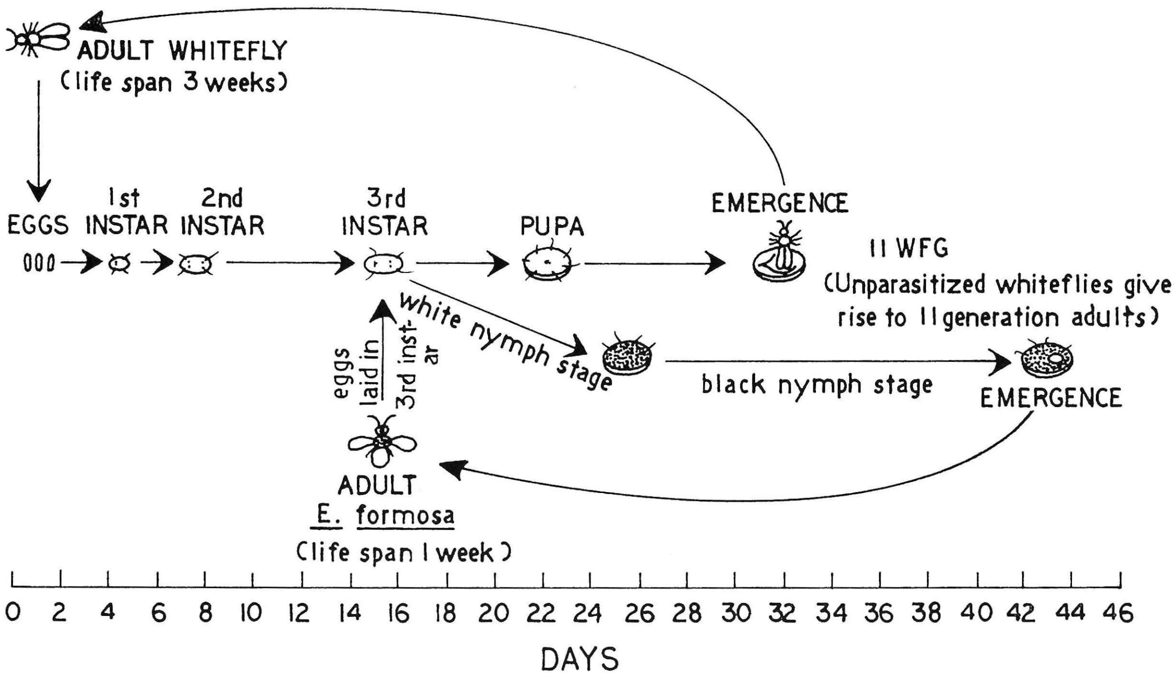


FIG. 5.—Encarsia **searching for whitefly nymphs.**



LIFE CYCLES OF THE GREENHOUSE WHITEFLY AND ITS PARASITE, ENCARSIA

Harbaugh, Brent. J. Amer. Soc. Hort. Sci., 101(3):228-233, 1976.

FIG. 6.—Illustration of how life cycles of host and parasite relate to each other.

TABLE 1.—Estimated Area (ha)* of Greenhouse Vegetable Production on Which Natural Enemies Are Used in Some European Countries (12).

	Encarsia	Phytoseiulus
Belgium	30	< 5
U. K.	> 50	> 50
Finland	< 10	< 10
France	< 10	< 10
The Netherlands	600	200
Norway	< 5	< 10
Poland	< 5	< 5
Romania	< 5	< 5
Sweden	< 20	< 20

*1 ha = 2.471 a.

pesticide resistance) soon became apparent. One big advantage was the usual reduction in cost for insect control. Details on prices of natural enemies are discussed below. Another plus was an increase in yields on many crops simply by not applying pesticides as often (1). Repeated applications of many pesticides apparently were causing subtle injury to plants that was not observed.

Most success with natural enemies has been obtained on vegetable crops because of their ability to tolerate low levels of insects and mites and still produce high fruit yields. On ornamentals, the presence of any insects or mites, although not reducing yields, reduces the beauty and hence value of a plant. The objectives of an IPM program need to be adjusted accordingly and should be aimed at elimination of pests (and natural enemies) prior to sale of an ornamental plant.

REARING, DISTRIBUTION AND COST OF NATURAL ENEMIES

Rearing procedures differ considerably, especially for *Encarsia*, depending on the acreage using natural enemies and individual preferences of those doing the rearing.

Phytoseiulus mites are always raised on spider mites feeding on bean plants (usually *Phaseolus vulgaris*). Two rearing areas are required: one to rear spider mites without *Phytoseiulus* and another to allow the predator to feed and develop on the spider mite population. Predators are raised and sold commercially, or individual growers can rear their own predators, with a little effort, to assure themselves of a constant supply.

Encarsia-rearing facilities and procedures are quite different. Much rearing in Europe and Canada utilizes a method developed at the Cheshunt Experimental Station in England. This system is being used at the OARDC. Whitefly-susceptible host plants (usually tomato, cucumber,

TABLE 2.—Approximate Cost (U. S. $) of Natural Enemies in Several Countries.

Encarsia formosa	
Sweden	$ 10.00/1,000
U. K.	4.50/1,000
Canada	2.50/1,000
Netherlands	780.00/ha (including consultant service)
Phytoseiulus persimilis	
Sweden	$ 62.50/1,000
Norway	100.00/1,000
U. K.	30.00/1,000
Netherlands	780.00/ha (including consultant service)

Needed (approximate): 5-10/plant (**Encarsia**); 1/plant (**Phytoseiulus**). Ornamentals may require more.

or tobacco) are grown in a greenhouse and infested with whiteflies. When suitable nymph stages are present, *Encarsia* is introduced. Parasitized whiteflies are then harvested, beginning at the bottom of the plant.

The cost of natural enemies also varies widely (Table 2). Although some variation in prices is due to subsidies, cooperatives, included consultant services, etc., this information does not fully explain the differences.

Natural Enemy Introduction

Introductions can be made in any of several ways and still achieve desired results:

1) "Classical" or "Pest-in-First" Method. This procedure was developed at the Glasshouse Crops Research Institute (GCRI) in England. It calls for the establishment of a uniform population of whiteflies or spider mites at a known level and then making precisely timed introductions of natural enemies.

The major hindrance to using this method is the reluctance of growers to introduce pests into their greenhouses. A recent study comparing two introduction methods for *Phytoseiulus* (6) indicated no advantage to the pest-in-first method compared with introduction when spider mites were first seen.

2) Introduction After Pests Seen, Multiple Introductions ("Dribble" Method. Introducing natural enemies after pests are first seen is important when using *Phytoseiulus* for spider mite control (2) because of the cost and the necessity of establishing the predator before spider mite numbers become too high. Usually, only one introduction is made on a crop.

The multiple introduction or the "dribble" method is used when *Encarsia* is employed for whitefly control. For example, in The Netherlands, four successive *Encarsia* introductions are made 2 weeks apart (13) when controlling whiteflies on greenhouse tomatoes, to make sure suitable whitefly stages are present and parasites become established. The first introduction is made after adult whiteflies are seen.

This procedure is being utilized in experiments at the OARDC.

RESULTS OF TRIALS AT OARDC

The authors have been successful in controlling whiteflies on tomato, cucumber, and poinsettia stock plants following *Encarsia* introduction schedules developed in England and The Netherlands. The total number of parasites introduced per plant were: tomatoes 5-7.5, cucumbers 7-10, and poinsettias 1-2. Figure 7 and Tables 3-5 show typical results obtained. In the poinsettia experiment, *Encarsia* migrated

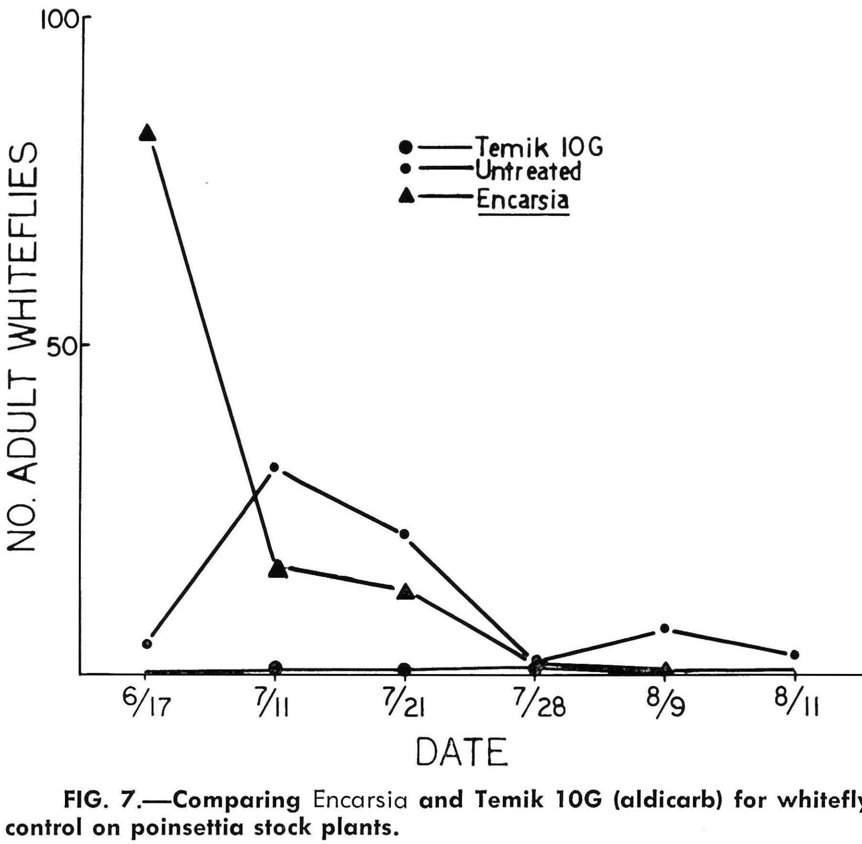


FIG. 7.—Comparing Encarsia **and Temik 10G (aldicarb) for whitefly control on poinsettia stock plants.**

to untreated plants. Although some problems remain, it is believed that *Encarsia* can be used commercially if adequate rearing and distribution facilities are developed.

Excellent results have been obtained by introducing *Phytoseiulus* predators onto cucumber plantings (at one or two predators per plant) in several experiments, including one commercial trial. Figure 8 shows the typical pattern of host and predator. After 6-8 weeks, spider mite populations began to decline and were eventually eliminated.

Results with *Phytoseiulus* on ornamental plants have been mixed, and efforts are continuing to develop satisfactory techniques. In one trial

TABLE 3.—Encarsia **Parasites for Whitefly Control on Greenhouse Tomatoes, Wooster Ohio, 1977.**

	Week After First Encarsia Introduced*			
	1	4	7	10
No. whitefly adults per two leaflets†	1.4	1	0.6	0.5
Percent nymphs parasitized (black scales)‡	0	60	58.7	55.4

***Encarsia** introduced on Sept. 2 (1.5/plant), Sept. 20 (3/plant), Oct. 5 (3/plant).
†Adults recorded on two apical leaflets on 40 plants (50% of plants in compartment).
‡Percent parasitism estimated on two subapical leaflets on 40 plants.

TABLE 4.—Encarsia **Parasites for Whitefly Control on Greenhouse Cucumbers, Wooster, Ohio, 1978.**

	Week After First Encarsia Introduced*			
	1	4	7	10
No. whitefly adults per apical leaf†	0.3	0.2	0.2	0.2
Percent nymphs parasitized (black scales)‡	0	25.8	13.1	32.8

***Encarsia** introduced on June 13 (4/plant) and July 5 (3/plant).
†Adults recorded on two apical leaves on 20 plants (= 25% of plants in compartment).
‡Percent parasitism estimated on two subapical leaves on 20 plants.

TABLE 5.—Encarsia **Parasites for Whitefly Control on Poinsettia Stock Plants, Wooster, Ohio, 1977.**

	Week After Encarsia Release*			
	2	4	5	12
No. whitefly adults per apical leaf†	0.3	106.9	11.5	0.1
Percent nymphs parasitized (black scales)‡	0.8	12.9	50.7	74.4

***Encarsia** introduced on June 4 (2/plant).
†Adults recorded on two apical leaves on 15 plants.
‡Percent parasitism estimated on two subapical leaves on 15 plants.

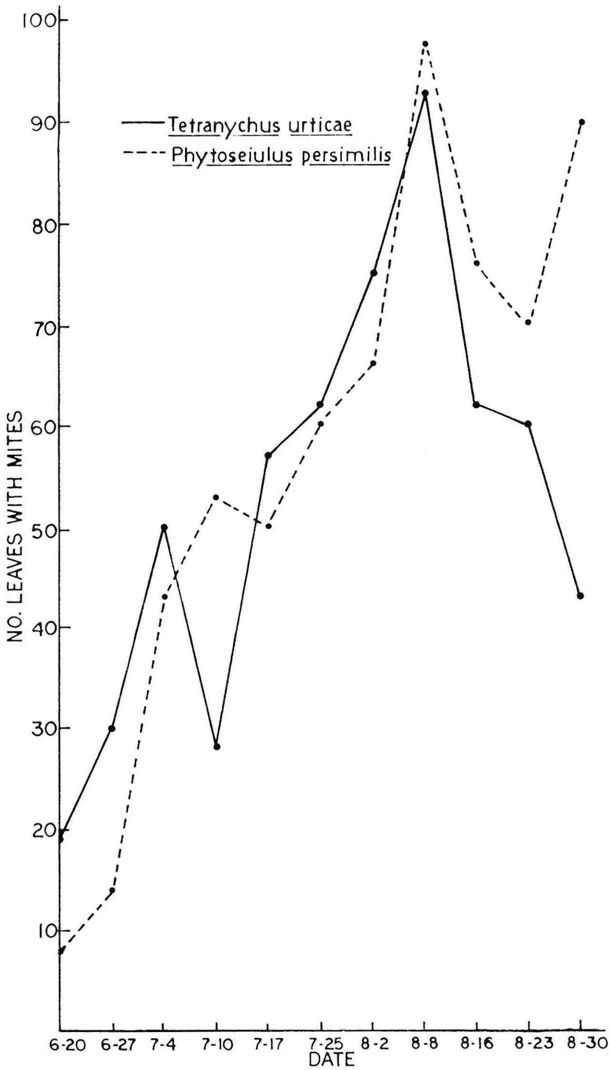


FIG. 8.—Using Phytoseiulus **to control** T. urticae **on greenhouse cucumbers.**

on roses conducted in OARDC greenhouses, excellent control was achieved when predators were introduced at five per plant (Fig. 9). Note that spider mite numbers remained low on upper foliage, which is the part of the plant sold. However, at rates lower than this, including one experiment in a commercial greenhouse, results have not been satisfactory.

Experiments are continuing with predators on several ornamental plant species, using different numbers of spider mites in an effort to define what is necessary to obtain control. Success on ornamental plants probably depends to a large extent on low spider mite populations initially, as well as relatively high numbers of predators at the first introduction. This might affect the economics of control with natural enemies compared with chemical miticides. A potential problem is that spider mite damage needs to be kept at a very low level on an ornamental plant compared with food crops.

Leafminers, *Liriomyza sativae* (Blanchard), have become serious problems on tomato, cucumber, and chrysanthemum, apparently due to tolerance of presently registered insecticides. For the past few months

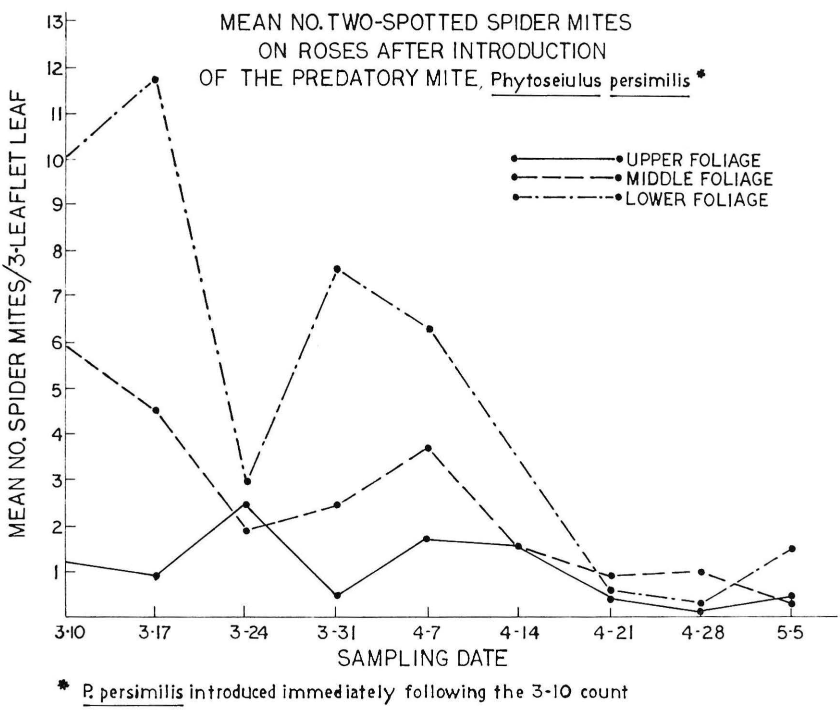


FIG. 9.—Using Phytoseiulus **to control** T. urticae **on greenhouse roses.**

the authors have been collecting hymenopterous parasites associated with leafminers outdoors. To date, four different species have been collected. The two most abundant species are *Diglyphus pulchripes* (Crawford) which emerges from leaf mines, and *Opius dimidiatus* (Ashmead) which emerges from leafminer pupae. Attempts will be made to determine the most efficient species (in cooperation with Dr. Robert McClanahan of Harrow, Ontario, who will work with parasites found in Canada) and to conduct experiments in leafminer control.

In one experiment, parasites (mostly *D. pulchripes*), were introduced into a small greenhouse compartment containing tomato plants heavily

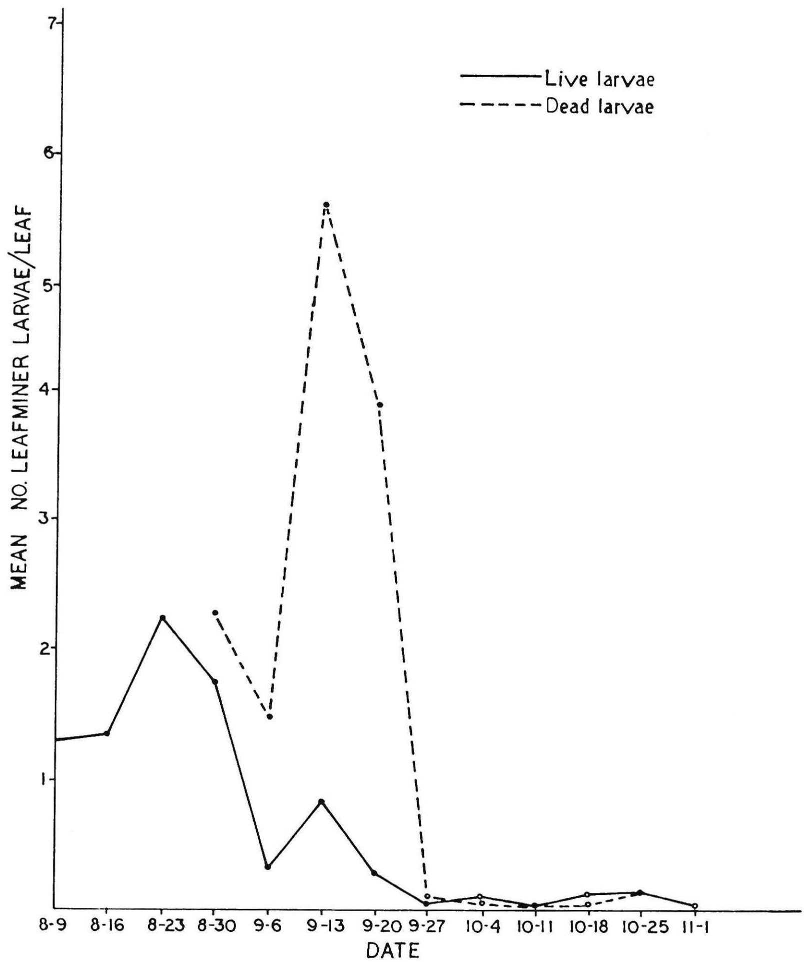


FIG. 10.—Control of Liriomyza sativae **on greenhouse tomatoes with hymenopterous parasites.**

infested with leafminers to determine if leafminer populations would be reduced. Parasites were introduced by placing several bean plants containing parasitized leafminer larvae among tomato plants. Results (Fig. 10) were encouraging because leafminer populations decreased rapidly, with a high percentage of leafminer larvae being parasitized. Nearly complete elimination of leafminers was obtained in 8 weeks. No attempt was made to record the number of parasites introduced.

This work is very important to this program. Without adequate biological methods for leafminer control in Ohio greenhouses, it is doubtful whether IPM programs will be successful.

INTEGRATION WITH PESTICIDES

In many cases, even with the relatively simple pest-natural enemy systems described above, pesticides are necessary to regulate whitefly or spider mite populations, or control additional insects and plant diseases. Materials used can be in one of several categories: 1) applied prior to introduction of natural enemies; 2) relatively harmless to natural enemies, no matter when applied; and 3) applied in a way to minimize contact with natural enemies. Studies to evaluate pesticides for their compatibility with natural enemies are underway in many areas, including the OARDC.

Current efforts are directed toward those materials which may be compatible with *Phytoseiulus* because they are extremely sensitive to many insecticides, miticides, and some fungicides. Several materials have been evaluated in trials to locate miticides which could be used to regulate a spider mite population in combination with *Phytoseiulus*. Fenbutatin-oxide (Vendex 50 WP) has been the most satisfactory (of those now on the market). Other new miticides also are promising but are not yet registered. Results of both laboratory and commercial trials with fenbutatin-oxide indicated that the recommended application rates of .03 - .06% AI could be used to regulate spider mite populations with minimal harm to predator adult survival or egg deposition.

Other pesticides, however, are not harmless, and their use will need to be restricted when predator mites are being used. An example of such a pesticide is acephate (Orthene 75 SP), a relatively non-toxic broad-spectrum material registered for aphid and leafroller control on certain greenhouse crops. OARDC experiments indicated a long-lasting effect (21 days) on predators through contact, residue, or the food chain, even at application rates lower than normal.

Each pesticide proposed for use in greenhouses will need to be tested for its effect on natural enemies. Obviously, the more natural enemies being used, the greater the difficulty in locating compatible pesticides, and probably some hard choices and trade-offs to achieve a satisfactory integrated system will be involved.

Recently projects have been initiated to develop pesticide-resistant strains of *Phytoseiulus*. For example, a diazinon-resistant strain is now available in The Netherlands (Woets, personal communication), and the genetics of resistance are being studied (9). Increased knowledge in this area should be of great value, particularly if *Phytoseiulus* is to be used on ornamental plants subject to attack by a wide range of pests.

OUTLOOK FOR IPM IN U. S. GREENHOUSES

Smith and Webb (10) reported that 30 insect and mite species sometimes damage greenhouse crops in the U. S., and that this will cause serious problems in implementing a practical IPM system for U. S. growers. Other reasons were cited why the task will be more difficult in the U. S. than in Europe, including warmer summer temperatures (5-10° C higher), migration of pests made easier because of continuous land connection with subtropical areas, and no East-West mountain barriers. The authors felt that the conditions in northern Europe resulted in relatively few pests (whiteflies, mites, aphids), and that these pests occurred predictably and thus were easier to control biologically.

Although much more work needs to be done, results of these and other experiments indicate that there is a possibility of successfully using IPM on some U. S. greenhouse crops. How soon this occurs depends on development of pesticide resistance, registration of selective pesticides and/or application methods, modification of growing practices, and consumer acceptance of some insect pests or damage on the finished plant.

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The Ohio Agricultural Experiment Station, as the Center was called for 83 years, was established at The Ohio State University, Columbus, in 1882. Ten years later, the Station was moved to its present location in Wayne County. In 1965, the Ohio General Assembly passed legislation changing the name to Ohio Agricultural Research and Development Center—a name which more accurately reflects the nature and scope of the Center's research program today.

Research at OARDC deals with the improvement of all agricultural production and marketing practices. It is concerned with the development of an agricultural product from germination of a seed or development of an embryo through to the consumer's dinner table. It is directed at improved human nutrition, family and child development, home management, and all other aspects of family life. It is geared to enhancing and preserving the quality of our environment.

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Mahoning County Farm, Canfield: 275 acres

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North Appalachian Experimental Watershed, Coshocton, Coshocton County: 1047 acres (Cooperative with the Science and Education Administration/Agricultural Research, U. S. Dept. of Agriculture)

Northwestern Branch, Hoytville, Wood County: 247 acres

Pomerene Forest Laboratory, Coshocton County: 227 acres

Southern Branch, Ripley, Brown County: 275 acres

Vegetable Crops Branch, Fremont, Sandusky County: 105 acres

Western Branch, South Charleston, Clark County: 428 acres